Survey of Bats in Southeast Alaska with Emphasis on Keen's Myotis (Myotis keenii)

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Abstract

Knowledge of the distribution and natural history of bats in Southeast Alaska is limited. We conducted capture and acoustic surveys for bats throughout Southeast Alaska in 2005 and continued surveys on Prince of Wales Island in 2006. We documented capture success, relative abundance, morphology, and periods of reproduction for each species. Capture success varied by species, location, and type of capture site. Little brown myotis (*Myotis lucifugus*; Le Conte 1831) were captured most frequently, followed by California myotis (*M. californicus*; Audubon and Bachman 1842), Keen's myotis (*M. Keenii*; Merriam 1895), and long-legged myotis (*M. volans*; Allen 1866). We captured little brown myotis throughout the region, Keen's and California myotis as far north as Juneau, and long-legged myotis in the southern part of the region. Silver-haired bats (*Lasionycteris noctivagans*; Le Conte 1831) were not captured, but were sighted on Prince of Wales Island and acoustic data indicate they may occur as far north as Juneau. Based on low rates of detection, all species appear to occur in low densities in Southeast Alaska. Better understanding of population status and trends, habitat ecology, and response to forest management is needed to identify essential habitat elements and prioritize conservation strategies in this region.

Introduction

Existing data are limited regarding the distribution and natural history of bats in Southeast Alaska (MacDonald and Cook 1996, Parker and Cook 1996, Parker et al. 1997). The challenges associated with observing volant, nocturnal animals are compounded in the temperate rainforest of Southeast Alaska by the rugged terrain, wet climate, and putative low densities of bats. Due to the limited availability of data, it is not certain whether the apparent rarity of bats in Southeast Alaska is a result of the species occurring at their distributional limits, ecological factors, or an artifact of inadequate investigation.

The little brown myotis (*Myotis lucifugus*; Le Conte 1831), California myotis (*M. californicus*; Audubon and Bachman 1842), long-legged myotis (*M. volans*; Allen 1866), the silver-haired bat (*Lasionycteris noctivagans*; Le Conte 1831), and Keen's myotis (*M. keenii*; Merriam 1895) occur in Southeast Alaska. The little brown myotis appears to be the most abundant species of bat in Alaska (Parker et al. 1997), and has been recorded as far north as Fort Yukon (Hall 1981) and Fairbanks (Fenton and Barclay 1980, Parker et al. 1997). The California myotis has only been documented in Southeast Alaska from 5 specimens found on or near Prince of Wales Island (ca. 54-56° N latitude; Grinnell 1918, Parker et al. 1997). Five specimens of long-legged myotis are recorded from Southeast Alaska; the northernmost location being Admiralty Island (ca. 57.5° N latitude; Grinnell 1918, West 1993, Parker et al. 1997). Four specimens of silver-haired bats were collected as far north as Juneau in Southeast Alaska (Barbour and Davis 1969, Parker et al. 1997). Only two specimens of Keen's myotis existed from Southeast Alaska; one found on Wrangell Island in 1887 and one from northern Prince of

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Wales Island in 1993 (Parker and Cook 1996, Parker et al. 1997). A third specimen collected on Chichagof Island and originally identified as Keen's myotis (Parker and Cook 1996), was later confirmed through genetic analysis to be a little brown myotis (Tanya Dewey, University of Michigan, personal communication).

The Keen's myotis may have the most restricted range of any species of bat in North America and occurs from Southeast Alaska through southwestern British Columbia and northwestern Washington (van Zyll de Jong 1979, van Zyll de Jong and Nagorsen 1994, Parker and Cook 1996). Due to its rarity, it was listed as a species of special concern in 1988 by Canada's Ministry of Environment. However, it has since been down-listed to 'Data Deficient' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) due to difficulties distinguishing it morphologically and genetically from long-eared myotis (*M. evotis*) and insufficient data regarding population status and trends and basic natural history (COSEWIC 2003).

Southeast Alaska is thought to be the northern distributional limit for all species of bat that occur there and each species is thought to be rare in this region except the little brown myotis (Parker et al.1997). Still, the conservation status of bats in Alaska remains unclear due to the lack of information pertaining to their distribution, population status and trends, and region-specific ecology. Moreover, the temperate rainforest of the Pacific Northwest is rapidly being altered by timber harvest (DeGange 1996, Iverson et al. 1996, USDA Forest Service 1996). These rainforests comprise a unique biome in North America and caution should be taken in extrapolating ecological knowledge from other parts of a species' range. Therefore, many questions regarding ecological requirements of bats within this system need to be addressed. We examined presence and distribution of bats using capture and acoustic techniques along a latitudinal gradient in Southeast Alaska. We documented ranges in external morphological characteristics and timing of reproductive periods for each species and, using multiple techniques in a variety of habitat types, we determined how and where to effectively detect each species. The baseline information we acquired regarding their distribution, reproductive periods, and effective means of capture can be used to establish a framework for future monitoring efforts of bats in Southeast Alaska.

Methods

Study Area

Southeast Alaska consists of the Alexander Archipelago and a narrow strip of mainland adjacent to British Columbia and extends from approximately 54° to 60° N latitude (Figure 1). The landscape is mountainous with coastal coniferous rainforest, muskeg bogs, marshlands, alpine areas, and glaciers with their associated outwash plains and ice fields. The glaciated St. Elias and Fairweather mountain ranges essentially isolate the region from south-central Alaska (Anthony and Tunley 1976). The region is approximately 9.3 million ha in size and 48% is classified as forest (van Hees 2003). This classification of 'forest' includes a mix of old growth, even- and uneven-aged second growth, muskegs, alpine areas, and grass flats (Alaback 1982, van Hees 2003). Dominant forest types are western hemlock (*Tsuga heterophylla*), western hemlock-Sitka spruce (*T. heterophylla-Picea sitchensis*), and mixed conifer (Alaback 1982, van Hees 2003). The maritime climate is characterized by cool summers and mild winters, high humidity, and high precipitation. Monthly average temperatures from May to September range from 6-13 °C and monthly average precipitation ranges from 2.5–29.7 cm (National Oceanic and Atmospheric Administration, www.noaa.gov, accessed June 2007).

Captures

We captured bats and recorded their echolocation calls to assess their presence and distribution across a broad range of habitats along a latitudinal gradient in Southeast Alaska. We captured bats in Yakutat, Juneau, Chichagof Island, Mitkof Island, Wrangell Island, and Prince of Wales Island from 13 May to 31 August 2005, and we continued survey efforts with emphasis on Keen's myotis on Prince of Wales Island from 20 May to16 Aug 2006. All protocols were approved by the Animal Care and Use Committee of Oregon State University.

We attempted captures only at sites where bat activity was verified with sightings, the presence of guano, or recordings of echolocation calls using echolocation detectors (Anabat II detectors-Titley Electronics, Ballina NSW, Australia). Most captures were conducted over rivers, creeks, and ponds. Aquatic environments are important areas

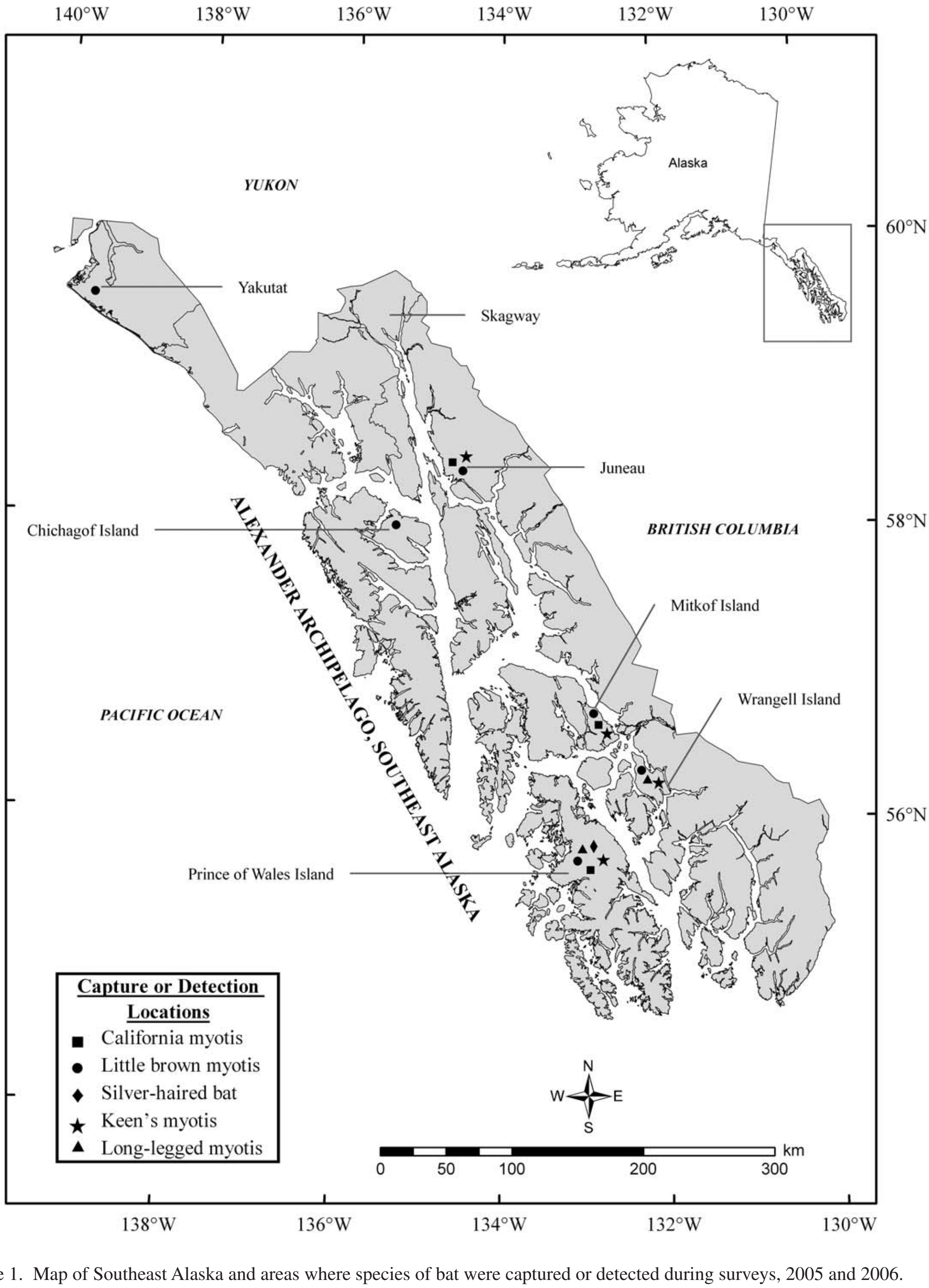

Figure 1. Map of Southeast Alaska and areas where species of bat were captured or detected during surveys, 2005 and 2006.

of bat activity because they provide drinking water and relatively high abundance of insect prey (Thomas 1988, Grindal et al. 1999, Hayes 2003) and bats use these areas more often than upland habitats (Parker et al. 1996, Grindal et al. 1999). We also attempted captures on roads and trails within forests because these habitats are often used as flyways by bats (Verboom and Huitema 1997, Grindal 1998, Law and Chidel 2002, Lloyd et al. 2006). Also, we contacted the public through flyers, newspaper classifieds, and other forms of community outreach to acquire knowledge of locations of bat activity and buildings with known or suspected roosts. Buildings and structures were suspected of being roosts if bats had been observed or guano was found in or around the structure.

We used several techniques separately and simultaneously to increase likelihood of captures and detection of each species. We captured bats using mistnets (Kunz and Kurta 1988) and four-banked harp traps (G5 Bat Trap, Bat Conservation and Management, Inc., Carlisle, PA, USA; Francis 1989) suspended outside roosts and over water and flyways. At selected locations, mistnets were also mounted on pulley systems from 20-30 ft stacked steel poles (Tom O'Shea and Dan Neubaum, U.S. Geological Survey, personal communication). In 2006, we focused efforts on capturing Keen's myotis and most capture attempts were made with mistnets placed over water or trails where nets spanned the entire corridor. We deployed echolocation detectors at capture sites in an attempt to detect bats that were not captured.

Capture Effort

In 2005, we surveyed bats across the region to ascertain the prevalence and distribution of each species. In 2006 our main focus was to capture Keen's myotis on Prince of Wales Island for telemetry studies (Boland et al. 2009) although we opportunistically captured and collected data on other species. Analyses of capture success and effort were restricted to capture attempts with mistnets, including stacked mistnets. Captures at roosts were excluded from analyses of effort.

We measured capture effort in units of "net-area hours." We calculated net-area hours by summing the total area of mistnets opened each night multiplied by the number of hours nets were open (m^2 net × hours). Capture per unit effort was determined by dividing the number of bats captured in mistnets by number of net-area hours staged. We determined the effort required to capture each species in each area sampled and at each type of site. Types of sites included rivers, creeks, ponds, roads, and trails. Rivers were distinguished as flowing waterways greater than 12 m wide with variable depths. Creeks were less than 12 m wide and less than 1 m deep.

Morphology and Reproduction

We identified species based on morphological characteristics and pelage (Nagorsen and Brigham 1993). For each bat, we recorded age, sex, reproductive status, and lengths of ear, tragus, thumb, foot, and forearm. We measured lengths of ear and tragus from the inside base notch to tip, the thumb from base of joint to base of nail, and the foot from base of toenails to start of ankle. To confirm identifications made in the field with DNA analyses, we collected a tissue biopsy with a 2 mm biopsy punch from the wing of each individual identified as Keen's myotis and a subset of individuals from all other species. Character data for DNA analyses of Keen's myotis were taken from double-stranded mitochondrial sequences of the cytochrome *b* gene and character data for the little brown myotis were taken from single-stranded sequences (Dewey 2006).

We classified reproductive status of female bats into 5 categories: pregnant, lactating, post-lactating, parous (evidence of reproduction at some point in the past, but not currently pregnant or lactating), and nulliparous (no evidence of previous reproduction) (Anthony 1988). Females in early stages of pregnancy (i.e., before the fetus is large enough to detect) were likely misdiagnosed as not pregnant. Males were identified as reproductive if testicles were enlarged and descended, and non-reproductive if otherwise. We distinguished juveniles from adults by transilluminating the wing and examining finger bones for the presence of cartilaginous epiphyseal plates (Anthony 1988).

Results

Captures

We attempted captures with mistnets on 118 nights at 99 different sites, including creeks, rivers, ponds, trails and roads. We caught 308 bats comprising four of the five species that were previously known to occur in the region (little brown myotis, California myotis, long-legged myotis, and Keen's myotis) and we sighted and acoustically detected the silver-haired bat. We captured 226 bats in mistnets while they were foraging or commuting and we captured 82 emerging from roosts. Identifications from DNA analyses confirmed all identifications made in the field.

We caught 163 little brown myotis in mistnets as they were foraging or commuting. We caught 62 emerging from roosts in buildings, and 1 from a roost in a tree. The little brown myotis is likely the most abundant species of bat in Southeast Alaska, as it comprised 87% of mistnet captures throughout the region in 2005. On Prince of Wales Island, little brown myotis comprised 68% of mistnet captures in 2005, whereas in 2006, when we used capture techniques that specifically targeted Keen's myotis, they comprised only 34% of mistnet captures. Little brown myotis were present in each area sampled and was the only species captured in Yakutat and on Chichagof Island. Fifty-five percent of little brown myotis captured in mistnets were captured over creeks and 29% were captured over rivers (Table 1).

We caught 29 California myotis in Juneau and on Mitkof and Prince of Wales Islands. In 2005, only 6% of mistnet captures throughout the region were California myotis. On Prince of Wales Island, California myotis comprised 13% of mistnet captures in 2005 and 30% in 2006. Sixty-two percent of captures of California myotis during 2005 and 2006 were on creeks.

We captured two long-legged myotis in 2005 on Wrangell and Prince of Wales Islands, comprising only 1% of mistnet captures for that year. Eight individuals were captured on Prince of Wales Island in 2006 (13% of all 2006 captures). All but one long-legged myotis were netted over creeks.

We captured 24 Keen's myotis while they were foraging or commuting and 19 emerging from a roost in a tree. In 2005, Keen's myotis were found in all localities except Chichagof Island and Yakutat, yet they comprised less than 6% of mistnet captures. On Prince of Wales Island, Keen's myotis comprised approximately 13% of mistnet captures in 2005 and 23% of mistnet captures in 2006. Seventy-one percent of Keen's myotis captured in mistnets in 2005 and 2006 were captured over creeks.

On Prince of Wales Island a silver-haired bat flew in several circles approximately 1.5 m from the observer (JLB) while an echolocation detector at a distance of about 2.5 m recorded its calls. We recorded echolocation calls with frequencies and shape characteristic of silver-haired bats on two occasions in Juneau, four occasions on Prince of Wales Island, and two occasions on Wrangell Island, but positive identification of those calls cannot be confirmed. We can say with confidence that the calls were not from Myotis spp.; however, echolocation calls of big brown bats (*Eptesicus fuscus*; Palisot de Beauvois 1796) have similar structure, length, and frequency as calls of silver-haired bats (Betts 1998).

Capture Success

Number of captures per unit effort (CPUE) was highest for little brown myotis, in all areas and during both years (Table 2). In 2005, CPUE for little brown myotis was much higher than any other species and was highest along rivers. In 2006, capture success for little brown myotis was highest along creeks, although it was nearly as high on ponds (Table 3). In 2006 on Prince of Wales Island, most capture attempts were made at sites where mistnets spanned entire corridors to target captures of Keen's myotis; in this year, CPUE was more uniform among species. In 2005, CPUE was highest for Keen's myotis on Prince of Wales Island and for California myotis in Juneau, and Keen's, California, and long-legged myotis

TABLE 1. The proportion of individuals of each species and the proportion of all bats captured at each site type in 2005 and 2006, Southeast Alaska.

Site Type	California myotis	Keen's myotis	Little Brown myotis	Long-legged myotis	All bats
Creek (n=57)	0.62	0.71	0.55	0.90	0.59
Pond (22)	0.14	0.13	0.14	0.10	0.14
River (10)	0.03	0.00	0.29	0.00	0.22
Road (4)	0.03	0.04	0.01	0.00	0.01
Trail (6)	0.17	0.13	0.01	0.00	0.04

TABLE 2. Number of bat captures per unit effort for all species by locality in 2005 and 2006, Southeast Alaska. Total effort = area of net × hours.

Locality	Year	Total effort	California myotis	Keen's myotis	Little brown myotis	Long-legged myotis	All bats
Yakutat	2005	6700	0	0	0.00597	0	0.00597
Chichagof Is.	2005	9383	0	0	0.00298	0	0.00298
Juneau	2005	6934	0.00058	0.00029	0.00274	0	0.00361
Mitkof Is.	2005	10253	0.00010	0.00020	0.00078	0	0.00107
Wrangell Is.	2005	11634	0	0.00009	0.00215	0.00009	0.00232
Prince of Wales Is.	2005	10772	0.00046	0.00037	0.00195	0.00009	0.00288
Prince of Wales Is.	2006	24278	0.00078	0.00062	0.00091	0.00033	0.00264

TABLE 3. Number of bat captures per unit effort for all species by site type in 2005 and 2006, Southeast Alaska. Total effort = area of net × hours.

2005	Total effort	California myotis	Keen's myotis	Little brown myotis	Long-legged myotis	All bats
Creek	36995	0.00016	0.00019	0.00195	0.00003	0.00232
Pond	9005	0.00044	0.00022	0.00222	0.00011	0.00300
River	8806	0	0	0.00545	0	0.00545
Road	683	0	0	0.00147	0	0.00147
Trail	187	0	0	0	0	0
Total	*55676*	*0.00018*	*0.00016*	*0.00253*	*0.00004*	*0.00291*
2006						
Creek	17082	0.00070	0.00064	0.00100	0.00047	0.00281
Pond	3073	0	0.00033	0.00098	0	0.00130
River	936	0.00107	0	0	0	0.00107
Road	858	0.00117	0	0	0	0.00117
Trail	2328	0.00215	0.00129	0.00086	0	0.00429
Total	*24278*	*0.00078*	*0.00062*	*0.00091*	*0.00033*	*0.00264*

TABLE 4. Mean morphological measurements (range) of bats captured in Southeast Alaska in 2005 and 2006.

Species	Ear (mm)	Tragus (mm)	Thumb (mm)	Foot (mm)	Forearm (mm)	Weight* (g)
California myotis	12.2 (11-14) n=25	5.6 (5-7) n=25	4.4 (4-5) n=21	5.5 (5-7) n=25	33.4 (31.2-34.8) n=25	6.0 (4.5-7.5) n=20
Keen's myotis	16.8 (15-18) n=41	9.0 (7.5-11) n=41	6.0 (5-6) n=21	7.5 (5-9) n=22	36.4 (34.6-39.8) n=41	6.1 (5-8) n=37
Little brown myotis	12.6 (9-15) n=177	6 (5-7) n=148	5.6 (5-7) n=53	8.0 (6-10) n=100	37.2 (34.2-39.8) n=147	7.7 (5.5-11) n=147
Long-legged myotis	11.3 (9-12) n=8	5.8 (5-6) n=8	5.7 (5-6) n=8	7.0 (5-8) n=8	38.2 (37-38.8) n=8	7.0 (7-8.25) n=7

* weight calculations do not include data from bats known to be pregnant.

were most efficiently captured on ponds. In 2006, CPUE of Keen's, California, and long-legged myotis were higher on Prince of Wales Island than in any area sampled in 2005. Overall, CPUE was greatest for Keen's and California myotis along trails and greatest for long-legged myotis along creeks.

Morphology

External morphology of each species in Southeast Alaska was, for the most part, similar to what is found in other parts of their range (Table 4; Fenton and Barclay 1980, Warner and Czaplewski 1984, Nagorsen and Brigham 1993, Simpson 1993). However, the range for adult body mass of Cali-

TABLE 5. Dates when reproductive, post-reproductive, and juvenile bats were captured in Southeast Alaska in 2005 and 2006.

	Pregnant	Lactating	Post-lactating	Juvenile
California myotis	Jun 19-28	13 Jun-12 Aug	12-15 Aug	6-12 Aug
Keen's myotis	4 Jul	7 Jul-7 Aug	14 Aug	24 Jul-7 Aug
Little brown myotis	4 Jun-2 Jul	4 Jun-8 Aug	24 Jun-24 Aug	19 Jun-25 Aug
Long-legged myotis	26 Jun	24 Jul	*	*

* No bats captured

fornia myotis (4.5-7.5 g) and Keen's myotis (5-8 g) in our study appears to be higher than what is reported in other parts of their range (3.3-5.4 g and 3.8-6.7 g, respectively; Hall 1981, Simpson 1993, Nagorsen and Brigham 1993, COSEWIC 2003). Body masses were from individuals that were not apparently pregnant, but as mentioned previously, some individuals may have been misdiagnosed if the fetus could not be felt with gentle palpations on the abdomen. Length of ear and tragus for Keen's myotis were slightly smaller for bats captured on Prince of Wales Island (15.0-18.0 and 7.5-11.5 mm, respectively) relative to measurements recorded for Keen's myotis in British Columbia (16.0-20.0 and 9.0-12.0 mm). However this result may be due to differences in measurement techniques. We made ear and tragus measurements from the inside base to tip; measurements made from the outside base of the ear or tragus would be longer.

Reproduction

During our study, we captured 12 California myotis, 6 Keen's myotis, and 2 long-legged myotis that were pregnant or post-partum (Table 5). We found 74 reproductive or post-reproductive female little brown myotis; however, 40 of the 74 were from the same maternity colony in Juneau and observed on the same night. Thirty-two juvenile bats were captured (2 California myotis, 2 Keen's myotis, 28 little brown myotis) from 19 June to 25 August. No reproductive males were captured in either year.

Discussion

Our survey results support previous knowledge that little brown myotis are widely distributed throughout Southeast Alaska (Parker et al. 1997). We found Keen's and California myotis approximately 300 km further north than previously recorded (Parker and Cook 1996, Parker et al. 1997), and although we did not capture long-legged myotis north of Prince of Wales and Wrangell Islands, previous records indicate they occur as far north as Admiralty Island in Southeast Alaska (Parker et al.1997). We recorded echolocation calls characteristic of those of silver-haired bats as far north as Juneau supporting prior evidence that silver-haired bats occur at that latitude (Barbour and Davis 1969); however, positive identification of these calls cannot be made due to the similarity of echolocation calls between big brown and silver-haired bats.

Our inability to capture silver-haired bats knowing they occur in Southeast Alaska suggests that, if densities are low, some species may not be detected in capture surveys. Although big brown bats have not been documented in Southeast Alaska, there is one record of a specimen in the interior of Alaska (Reeder 1965). However, big brown bats, like little brown bats, are generalists that frequently are found roosting in man-made structures (Kurta and Baker 1990, Williams and Brittingham 1997, Lausen and Barclay 2006). Big brown bats are also large relative to other species that occur in Southeast Alaska (Kurta and Baker 1990). If they occurred in the region and roosted in buildings, it is unlikely that big brown bats would go unnoticed. Nonetheless, given the possibility that big brown bats may occur in Southeast Alaska, the only positive identification we can make of echolocation calls belonging to silver-haired bats were the ones recorded on Prince of Wales Island, where visual identification occurred. Still, it is likely that the distribution of silver-haired bats extends at least as far as Juneau (Barbour and Davis 1969).

Surveys in 2005 targeted a broader range of species in a variety of habitats, whereas in 2006 the majority of effort was directed at capturing Keen's myotis. In 2005, nets were most frequently set up in aquatic habitats where physical obstruction created by vegetation or man-made structures (i.e., vegetative and structural clutter) was relatively low. In 2006, nets were most frequently arranged so as to block potential flight corridors under bridges or across trails and small creeks where clutter was relatively high. We learned that little brown myotis were more likely to be captured in uncluttered areas over water, which supports previous findings that little brown myotis may preferentially forage in open habitats (Fenton and Bell 1979, Saunders and Barclay 1992). Similar to Keen's myotis, capture success for California and long-legged myotis was higher where flight corridors were spanned with nets and surrounded by high vegetative or structural clutter.

The relative success of captures in different types of habitat and with different capture techniques may be explained by ecomorphology. Ecomorphology can be used to examine the relationship between morphological design and the ability of an organism to exploit its environment (Swartz et al. 2003). Wing morphology and body size influence wing loading and aspect ratio, which in turn affect in-flight maneuverability (Swartz et al. 2003). Kalcounis and Brigham (1995) found that individuals with higher wing loading foraged in less cluttered environments and attributed it to lower maneuverability. Measurements of forearm length and weight for each species captured in this study (Fenton and Barclay 1980, Warner and Czaplewski 1984, Simpson 1993, Nagorsen and Brigham 1993) suggest wing loading is higher for little brown myotis than California, Keen's, and long-legged myotis. Given their morphology and associated wing loading, little brown myotis may be less adept at flying in structurally cluttered environments and are therefore less willing to exploit habitat in relatively small corridors. California, Keen's, and long-legged myotis may be more maneuverable in flight and therefore more capable of exploiting forested environments and avoiding nets in open areas. However, long-legged, California, and little brown myotis are known to occur in open as well as forested habitats in other parts of their range (Fenton and Bell 1979, Warner and Czaplewski 1984, Saunders and Barclay 1992, Nagorsen and Brigham 1993, Vonhof and Barclay 1996, Brigham et al. 1997, Hayes 2003). Flexibility in the use of different habitat types may suggest that other factors, such as echolocation ability, dietary specialization, and food resource availability, may also explain habitat use by bat species in Southeast Alaska (Saunders and Barclay 1992, Lacki et al. 2007, Johnson et al. 2008, Ober and Hayes 2008).

Scope and Limitations

Calculations of relative abundance of each species can be influenced by the types of habitats sampled because use of habitats can vary among bat species. Although we sampled a variety of habitat types, our sampling design was primarily opportunistic and different results of relative abundance may be obtained with different sampling design and capture methodology.

Given the overall low numbers of captures per night, one night of relatively high captures could be very influential on calculations of capture success (as indexed by CPUE). For example, in 2006 we captured 19 California myotis on 9 different nights, but on one night captured 5 individuals on a trail; the only California myotis captured on a trail in 2006. Although 63% of mistnet captures of California myotis were on creeks and only 23% occurred on one trail, capture success was nearly three times higher on trails as compared to creeks. Capture success was highest for little brown myotis in each area sampled for each year, but was especially high for little brown myotis in Yakutat largely due to one night when 31 bats were netted at the same site. This site may have been located near a maternity roost because all bats were caught in nets over a river immediately after sunset, and only four of the individuals were male. This particular night was also highly influential in determining that capture success was highest on rivers for little brown myotis in 2005.

Conclusions and Management Implications

Given relative low rates of capture during this and previous surveys (Parker et al. 1997), densities for each species appear to be low in the region. Southeast Alaska is likely the northern limit for the ranges of California myotis, Keen's myotis, long-legged myotis, and silver-haired bats. Brown et al. (1995) suggest the abundance of a species is highest in the interior relative to the edge of its range because the environment is more suitable in the interior. An alternative view suggests that peripheral populations that are more isolated from ecological factors leading to extinction (e.g., habitat degradation and introduced competitors) may persist longest (Lomolino and Channell 1995). Regardless, Keen's myotis has a remarkably small range and all existing populations, regardless of size and location, may be critical for longterm viability.

All bat species have naturally low reproductive rates and in temperate climates, high precipitation and low ambient temperatures are associated with lowered reproductive success due to unsuccessful pregnancies and abstinence from mating (Grindal et al. 1992, Lewis 1993). Therefore, it is likely that the reproductive rate of bats at the northern limits of their distributional range is lower than those of conspecifics in southern parts of their range (Racey and Entwistle 2003). Furthermore, it is likely that climatic factors associated with high latitudes in Southeast Alaska impose energetic constraints on bats that keep population densities naturally low in the region.

Many factors contribute to species declines and risk of extinction. Intrinsic biological and ecological factors such as low reproductive rate and rarity may exacerbate consequences of extrinsic factors such as habitat loss (Racey and Entwistle 2003, Hayes and Loeb 2007). Currently, data are insufficient for conclusive determination of habitat associations for all species of bat in Southeast Alaska, but many are primarily associated with forested habitats in other parts of their range. Silver-haired bats are generally found in older coniferous or deciduous forests in northwestern North America (Kunz 1982, Barclay et al. 1988, Campbell et al. 1996, Nagorsen and Brigham 1993). The long-legged myotis and Keen's myotis are primarily associated with coniferous forests (Warner and Czaplewski 1984, Firman et al. 1993, Nagorsen and Brigham 1993, Hayes 2003) and female Keen's myotis on Prince of Wales Island appear to be primarily associated with old-growth forests for day roosting (Boland et al. 2009). Forests in Southeast Alaska, especially on private lands, are being rapidly clearcut (DeGange 1996, Iverson et al. 1996, US Forest Service 1996). To understand how the increasing rate of habitat loss and alteration affect population status and distribution of bats in Southeast Alaska, knowledge of the current status and future trends of populations and habitat associations for each species across multiple spatial scales is required. Determining the status and trends of bat populations in Southeast Alaska will require a commitment from wildlife and land management agencies to multiyear monitoring efforts using standardized protocols.

Keen's myotis is a highly maneuverable, forest-dwelling species and the results of this study suggest that capture success is highly dependent on capture methods that target these characteristics. If applied, the methods learned in this study can contribute to future success of monitoring efforts of Keen's myotis in Southeast Alaska and throughout their range.

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